Appendix B
Declaration of Enchao Yu Under
37 CFR §1.132

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Attorney Docket No. 361007-000012

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Yogendra Joshi, et al.	
Application No.: 09/828,564	Group Art Unit: 3743
Filed: April 6, 2001	Examiner: Nihir Patel
Title: Orientation-Independent Thermosyphon Heat Spreader	

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION OF ENCHAO YU UNDER 37 C.F.R. § 1.132

Sir:

I, Enchao Yu, declare as follows:

1. I am a Chinese citizen residing at 86 Shadywood, Irvine, California 92620.

2. I received a Bachelor of Science degree in Mechanical Engineering in 1985 from the Beijing Institute of Technology. In 1988, I received a Master of Science degree in Mechanical Engineering in 1988 from the same institution. I received a Doctor of Philosophy in Mechanical Engineering in 1997 from the University of Maryland at College Park.

3. I am not an inventor of the above-captioned patent application for United States Letters Patent (the "Application"). I understand that Dr. Yogendra Joshi is a co-inventor of the Application.

4. From 1994 to 1996, I studied under the supervision of Dr. Joshi at University of Maryland at College Park as a Ph.D. candidate. My field of

research related to electronic cooling and my Ph.D. dissertation was entitled "Passive Cooling of Discretely Heated Components by Combined Conduction, Natural Convection and Radiation."

5. From 1997 to 2000, I worked as a Principal Engineer for the R&D division of CFD Research Corp. in Huntsville, AL. When I left CFD Research Corp. I subsequently worked in the position of Staff Packaging Engineer with Newport Corp., then as a Thermal Mechanical Engineer with OptoIC Technology, and then as a Senior Packaging Engineer with Lightcross, Inc. until October 2003. In each of these organizations I was responsible for thermal design and analysis of electronic and optoelectronic components in these organizations.

6. Since October 2003, I have worked as an independent consultant in Irvine, California. My work includes the application of existing thermal technologies and the development and commercialization of new thermal technologies.

7. My curriculum vitae are provided as Exhibit A to this Declaration.

8. I am familiar with the Application, the references cited on the Applicant's Information Disclosure Statement and the Applicant's Supplemental Information Disclosure Statement, the references cited by the Examiner of the Application, the substantive Office Actions from the Examiner, and the Applicant's responses to substantive Office Actions.

9. I have personal knowledge of the design and operation of conventional thermosyphons and heat pipes used for the cooling of electronic circuit components.

10. The product claims of the present invention all require that the thermosyphon have a condenser on the periphery of an evaporator (as recited in claim 1, from which claims 2-38 depend, and in claim 39, from which claims 40-42 depend). Likewise, the same claims as amended require that the evaporator be substantially or completely full of liquid coolant. Such factors contribute to the present invention being substantially or completely orientation independent.

11. In the conventional thermosyphon art, a technical requirement is to have a vertically oriented device that has a condenser above an evaporator. The condenser must remain above the evaporator, as the liquid in the evaporator undergoes a phase change to vapor, which rises to the condenser. There the cooled vapor condenses to liquid and returns by gravity to the evaporator. The conventional thermosyphon, therefore, is not orientation-independent. The thermosyphon claimed in the Application (the "present invention"), however, is orientation-independent and has a condenser on the periphery of the evaporator. One of ordinary skill in the art would not be motivated to locate a condenser around the periphery of the evaporator, as this would be contrary to the technical requirement of vertical orientation of a conventional thermosyphon.

12. In the conventional heat pipe art, the practice is to have an evaporator connected to a condenser with either a wicking structure or a microfabricated grooves that transport a liquid coolant to the heat generating area on the electronic component. There the coolant evaporates and moves towards the cooler, lower pressure condenser, where it returns to liquid. Heat pipes may not be orientation-independent in cases where there is a layer of

coolant that must be deeper than the wicking structure or grooves in order to function, which drains to the lowest point in the evaporator. A conventional heat pipe requires a pressure gradient in its core for the movement of vapor from evaporator to condenser. The creation of this pressure gradient (higher pressure in the evaporator and lower pressure at the condenser) requires that the liquid be recessed into the wick at the evaporator, giving a smaller radius of curvature of the meniscus there, compared to that at the condenser. Thus for proper operation of the heat pipe, the evaporator wick should not be substantially or completely full of liquid, unlike in a boiling based device such as the present invention.

13. The Examiner rejected all claims based in part on US Patent No. 6,474,074 to Ghoshal, except claims 24, 26, 29, and 36, which were rejected on the basis of design choice. Ghoshal is a heat pipe design that operates by fluid return from the condenser to the evaporator by the wicking action of the capillary region. To function there must be a capillary region between the condenser and the evaporator (see Ghoshal Figure 2: capillary region 220, evaporator region 210, and condenser region 225). The liquid coolant, or transport fluid, of Ghoshal can only partially fill the Ghoshal evaporator based on Ghoshal's operating principles. Ghoshal requires that there be vapor in the evaporator region, which is transported by vapor channels 235 (see col. 4, lines 38-41). To leave the vapor channels open the evaporator cannot be substantially full of coolant. This also precludes Ghoshal from being orientation independent.

Ghoshal has neither a condenser on the periphery of the evaporator nor a substantially full evaporator as is required in claims 1-43 (directly or indirectly).

14. A person of ordinary skill in the art would not be motivated to combine any of the remaining cited references with Ghoshal, and there would be no expectation of success in doing so. Ghoshal's principal of operation would be changed or the device would not function.

15. In the present invention, fluid return from the condenser to the evaporator is by gravity, not by capillary force.

16. Based on the conventional design of thermosyphons, a person of ordinary skill in the art, with all of the cited references in hand, would expect that the condenser must be above the evaporator and that the device would not be orientation independent. The prior art provides motivation to stay with the types of designs reflected in the prior art.

17. Claims 1, 7, 17, and 43 were rejected as being obvious with respect to Ghoshal in view of Osakabe, US Patent Publication No. 2001/0023758 A1. With respect to claims 1 and 43, in addition to the discussion of Ghoshal in paragraph 13 above, Osakabe does not have a condenser extending around the periphery of its refrigerant vessel 32 (see Osakabe Figure 11). Both references lack the limitation of a peripheral condenser, and the references fail to teach or suggest all claim limitations.

18. With respect to claim 7, neither Ghoshal nor Osakabe teaches or suggests a porous component that provides re-entrant cavities. Ghoshal requires "hot point elements" that must have a tapered point (see col. 4, lines 34-

36). Osakabe discloses inner fins 34 (see Osakabe ¶ 0072, lines 4-6), without re-entrant cavities. Ghoshal does not function with formation of vapor bubbles, which could block its re-entrant cavities to prevent the return of liquid to the evaporator. There is no suggestion to modify or combine the references, or likelihood of success in doing so.

19. With respect to claim 17, which requires a full evaporator with the thermosyphon horizontal in one position, as discussed above in paragraph 13 Goshal cannot be modified with Osakabe to have a full evaporator and still function.

20. Claims 8-11, 18-22, 25, 32, and 39-42 were rejected as being obvious with respect to the combined teachings of Ghoshal and Anderson et al., US Patent No. 5,761,037.

21. With respect to claims 18-22, 25, 32, 39, and 40-42, claims 18-22, 25, 32, 40, and 42 relate to the level of liquid in the evaporator for various orientations. Claim 39 recites a thermosyphon having a substantially full evaporator at all orientations, with performance also being substantially independent of orientation. Claim 41 recites such a thermosyphon as part of a cooling enhanced electronic component. Anderson discloses a wicking manifold and states that the wicking manifold is operable with respect to any orientation (see col. 4, lines 3-5 and 33-38). Anderson's wicking manifold operates through capillary action in the wicking structure, and purports to spread the liquid, indicating that the evaporator region is less than full. To state that the wicking member/manifold is operable at any angle does not mean that the evaporator is

substantially full at any angle. Anderson discloses nothing about how to keep an evaporator substantially full at any orientation, and neither does Ghoshal, since in Ghoshal the evaporator cannot be substantially full and still function.

22. With respect to claim 8, which recites a grooved boiling enhancement structure and claim 11, which recites a boiling enhancement structure of open-celled foam, Ghoshal requires the use of tapered point "hot points" and therefore prohibits the use of Anderson's wicking manifold, and the references cannot be combined. Further, the function of the boiling enhancement structure of the present invention is to enhance boiling, whereas Anderson's structure is for wicking, two different functionalities.

23. Claim 23 was rejected as being obvious with respect to the combined teachings of Ghoshal and Brzezinski, US Patent No. 5,323,292. Brzezinski does not include an evaporator or evaporator plate. Instead there are two heat sinks (see Figure 1; col. 3 line 62 to col. 4, line 4). The fluid provides a thermal path and does not evaporate (see col. 5, lines 29-38: the thermally conductive fluid 58 fills the chamber formed by the first heat sink and the metallic membrane 56, which is not an evaporator). Further, Brzezinski does not disclose the walls as in claim 23. Claim 23 claims a condenser, which does not exist in Brzezinski, and more specifically, the cross-sectional shape of a condenser. Nor is such a shape disclosed in Ghoshal. This shape is shown in Applicant's figures 3, 7, 8, and 13. The combined references lack all the limitations of claim 23, fail to motivate or suggest combining the references, and there would be no expectation of success resulting in Applicant's invention.

24. Claims 26, 29, and 36 were rejected on the basis of design choice. Claim 26 recites a rectangular planar shape, and claims 29 and 36 recite a square shape. A variety of planar shapes may be used in accordance with the present invention. To be an embodiment of the present invention according to claims 26, 29, and 36, however, a thermosyphon of any planar shape must have dimensions that keep the evaporator substantially full at any orientation. A planar shape has a great impact on the overall evaporator and condenser dimensions (outside the plane). Therefore, selecting a planar shape is not simply a matter of design choice.

25. Claims 27, 28, 30, 31, 37, and 38 were rejected as being obvious with respect to the combined teachings of Ghoshal and Munekawa et al., US Patent No. 5,076,351. These claims provide dimensional requirements for thermosyphons according to the present invention. Munekawa is directed to a heat pipe and is inapplicable to the present invention. The shapes of heat pipes may vary. Evaporators and condensers in heat pipes may be sized as known to one of ordinary skill in the art. Unlike the present invention, Munekawa's condenser height is irrelevant to the liquid coolant volume and to the height of the evaporator. No liquid coolant resides in Munekawa's condenser. Further, the relationship between the Munekawa evaporator and the condenser has nothing to do with the orientation-independence of the heat pipe. A variety of variables must be considered in order to size and fill the thermosyphon in accordance with the present invention. Selecting the height of the condenser and evaporator, as well as the variables of evaporator and condenser lengths, is not known to one of

ordinary skill in the art. None of the references cited teaches or suggests such a geometric configuration. None has the purpose or result of providing an orientation-independent thermosyphon, achieved by maintaining a substantially full evaporator. The combined references lack disclosure of the limitations of these claims, and the subject matter between the two references is too different to be able to combine and achieve the present invention with any expectation of success. Nor is there any suggestion or motivation to combine the references.

26. The present invention solves long felt but unmet needs in the field of cooling electronic components. For many years electronic components and systems have been decreasing in size, while increasing in functionality. For the last ten years or so, which is a very long time in the electronics industry, these trends have pushed the limits of the capability of components for dissipating heat. The space within electronic systems available for heat dissipation has decreased, and this has been a persistent problem recognized by those of ordinary skill in the art (see, for example, the ABC News report at http://abcnews.go.com/sections/scitech/FutureTech/futuretech021216.html, attached hereto as Exhibit B). Product developers have long struggled to come up with new ways to cool electronic components that function in reduced space and in various orientations (see, for example, the recent cooling solution from Stanford University that utilizes a pump for orientation independent performance, described at http://www.wired.com/news/technology/0,1282, 60733,00.html, attached hereto as Exhibit C). Examples of electronic devices where such a need for orientation independence is felt include, but are not limited

to, devices that are moved by a user during operation such as handheld devices, laptop computers, video cameras, and devices in vehicles. Reduced size is a need felt in those devices as well as in, for example, desktop computers, printers, audio equipment, VCRs, DVD players, and televisions, among other things. Little improvement has been made over conventional heat spreaders (such as flat plates that act as a heat sink for an electronic component), heat pipes (including devices based on capillary action), thermosyphons (which are orientation dependent), or forced air or liquid cooling. The present invention, with its peripheral condenser and substantially or completely full evaporator as required by the claims, and its thin profile, has therefore met long felt but unsolved needs with respect to the reduction in size and orientation-independence of electronic devices.

27. It is my opinion that my clients will be interested in taking a license in the prospective patent once a final testing is completed and the funding is secured. It is my professional opinion that other companies would also be interested in taking such a license. I see no reason why the present invention cannot be commercially manufactured and sold. Though the present invention is not currently available for production, it is my opinion that the present invention will be commercially successful. This success will be the result of the advantages disclosed or inherent in the description in the Application, namely orientation independence and ability to perform well at the same or smaller size as conventional devices.

28. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

This 2nd day of June, 2004.

Enchao Yu

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ENCHAO YU

EDUCATION

University of Maryland, College Park, Maryland
Ph.D. in Mechanical Engineering, December 1996
Dissertation: Passive Cooling of Discretely Heated Electronic Enclosures by Combined Natural Convection, Conduction, and Radiation

Beijing Institute of Technology, Beijing, China
M.S. in Mechanical Engineering, March 1988
B.S. in Mechanical Engineering, July 1985

WORK EXPERIENCE

Consulting (11/03 – present)
Thermal design and development/commercialization of new thermal technologies

Lightcross, Inc., Monterey Park, California
Senior Packaging Engineer, (10/02 – 10/03)
Thermal/mechanical design of Optoelectronic components

OptoIC Technology, Inc., Irvine, California
Senior Thermal/Mechanical Engineer (07/01 – 09/02)
Thermal/mechanical design of Optoelectronic components

Newport Corporation, Irvine, California
Staff Packaging Engineer, Advanced Device Packaging (03/01 – 07/01)

CFD Research Corporation, Huntsville, Alabama
Principal Mechanical Engineer, (01/97 - 03/01)
Themal mechanical Design and Analysis

University of Maryland at College Park
Graduate Research Assistant, CALCE Electronic Packaging Research Center (08/93 - 12/96)

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SELECTED PUBLICATIONS

- E. Yu and Y. Joshi, Heat Transfer Enhancement from Enclosed Discrete Components Using Pin-Fin Heat Sinks, *Int. J. of Heat and Mass Transfer*, 45 (No.25), 4957-4966, 2002.
- E. Yu. et al., A Thermo-Electro-Mechanical Study of a VCSEL Array Package, *Advances in Electronics Packaging, InterPACK*, Maui, Hawaii, June, 1999.
- E. Yu, et al., Active Cooling of Integrated Circuits and Optoelectronic Devices Using a Micro Configured Thermoelectric and Fluidic System, *proceedings of ITHERM*, Vol. II, Las Vegas, Nevada, 2000.
- E. Yu, et al., Thermomechanical Design of Microchannel Cooled Semiconductor Laser Diode Array Package, *proceedings of SPIE on physics and simulation of optoelectronic devices*, San Jose, CA, 1999.
- E. Yu and Y. Joshi, Natural Convection Air Cooling of Electronic Components in Partially Open Compact Horizontal Enclosures, *IEEE Transactions on Components and Packaging Technologies*, Vol. 23, No. 1, 2000.
- E. Yu and Y. Joshi, Heat Transfer in Discretely Heated Side-Vented Compact Enclosures by Combined Conduction, Natural Convection, and Radiation, *Journal of Heat Transfer, Transactions of ASME*, Vol. 121, pp. 1002-1010, 1999.
- E. Yu, et al., Reduced Thermal Models of Electronic Packages for System Design Applications, *Advances in Electronics Packaging, InterPACK*, Maui, Hawaii, June, 1999.
- E. Yu, et al., A Computational Study of Two-Phase Jet Impingement Cooling of an Electronic Chip, *proceedings of SEMI-THERM XV*, San Diego, CA, 1999.
- E. Yu and Y. Joshi, Effects of Anisotropic Thermal Conductivity on Natural Convection Cooling of Discrete Heat Sources, *Numerical Heat Transfer*, Vol. 32, No.6, pp. 575-593, 1997. Also presented at *InterPACK, Advances in Electronics Packaging*, 1997.

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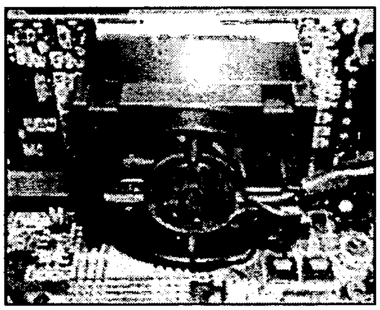
The "smart heat pipe" being developed by scientists at the Sandia National Labs is designed to cool computer chips without cumbersome heat sinks and fans, such as those seen above. (Paul Eng/ABCNEWS.com)

Cool Runnings

New Technologies to Keep Computer Chips Cool

By Paul Eng
abcNEWS

Dec. 16— The computer industry is in for a hot time — literally.

To produce ever-faster microprocessors, chip makers such as Intel and AMD have been cramming more and more microscopic transistors within the chips.

The current Pentium 4 chips, for example, have more than 42 million tiny electronic switches jammed into a space no larger than a postage stamp.

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But such tightly packed processors also produce much heat — as much a 50-watt light bulb.

Getting rid of that excess heat, which can damage delicate components and cause data to be lost, is becoming increasingly problematic. Already, some high-end desktop computers are using tiny, sophisticated water-cooling systems to beat the heat.

Scientists at Sandia National Laboratories in Albuquerque, N.M., have been working on an elegant solution for the military that could soon find its way to desktop and laptop computers.

A Mini-Maze of Methanol Pipes

The device was developed under a joint project with researchers at the Georgia Institute of Technology to figure out how to cool military electronics — radar systems and portable battlefield computers.

The "smart heat pipe" is a simple, flat copper plate that contains tiny hollow flat channels. The "pipes" measure about 7 microns thick — about the depth between the individual ridges of a human fingerprint — and carry liquid methanol.

When the plate is bonded to the microprocessor, the methanol is drawn to the hot spots by capillary action, much like the way kerosene travels up a wick. The heat vaporizes the methanol into gas, which naturally moves away from the hot spots.

The gas can be directed to take the heat to cooler spots — say the sides of the plate. As the gas cools, it condenses back to liquid and is drawn back to the hot spots to start the cooling process over.

Simple to Make, Easy to Add

Michael Rightley, principal member of the technical staff at Sandia, says that in development tests so far, the "smart heat pipe" has had twice the thermal conductivity of standard copper plates of similar size.

"It's hard to define the efficiency of the heat pipe," he says. So further testing and optimizing work will need to be done over the next year.

However, he notes that the production of the smart-pipe system doesn't require any complex machinery.

"It uses existing tools and photolithographic technology,"says Rightley. "So, they're relatively easy to make."

What's more, the flat heat pipe plates can be made to fit any design constraint — such as the tight spaces of a thin laptop or handheld computer.

More Than One Way to Cool a Chip

Computer chip makers say this is a step in the right direction when it comes to cramming more hot chips in ever tighter computer cases.

"In terms of passive heat solutions, this is the next step," says John Heinlein, a director at Transmeta Corp. in Santa Clara, Calif. "This is solid engineering. Everyone making laptops will benefit from this."

But Heinlein and others note that external cooling systems won't solve the problem completely. And chip makers are taking a multi-tier approach to develop cooler-running chips.

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For example, Transmeta's Crusoe chips have fewer transistors and use less electrical power to run cooler than standard Pentium chips for desktop computers. And while Crusoe-equipped PCs might not be as fast as desktops, "the average user will have more than enough performance for the type of computing they need," says Heinlein.

Meanwhile, Intel is also seeking cooler running chips by changing the design or architecture of its Pentium line of processors.

Wilford Pinfold, director of Intel's Microprocessor Research Labs, says its upcoming Banias processor will feature transistors that are smaller and optimized for power-efficiency. Built-in software code will even power down or switch off transistors so less power is consumed, producing a cooler chip.

"There are a lot of these technologies that we are looking at to improve the efficiency of the microprocessor that will prove the benefits of longer battery life and cooler running," says Pinfold. "There really is no one silver bullet."

Coming to a Chip Near You?

Still, many agree that a simple cooling solution such as Sandia's smart pipes will undoubtedly help.

Rightley says he and his team of researchers will continue to experiment on the device for the military. The goal: to develop an efficient cooling system for a powerful computer that can be worn by a soldier in the heat and muck of battle.

In the meantime, Rightley says Sandia is already in talks with a private company to take the patented technology out into the commercial world. If negotiations progress, computer makers may be able to incorporate smart-pipe technology into computers within a year. ■

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WIRED NEWS

How Computer Chips Keep Cool

By Leander Kahney

Story location: http://www.wired.com/news/technology/0,1282,60733,00.html

02:00 AM Oct. 08, 2003 PT

A Silicon Valley startup has developed a miniature water-cooling system for computer chips that functions much like a radiator in a car.

Cooligy, a company launched by three Stanford University mechanical engineering professors, said its Active Micro-Channel Cooling system is based on a thin patch of silicon with dozens of tiny pipes called microchannels etched into it.

Located just a millimeter from the surface of the chip, the dense, 3-D network of microchannels ferries a constant stream of cold water that conducts heat away from the computer processor to a radiator on the outside of the machine.

The system is powered by a small, solid-state pump that uses a unique "electrokinetic" process. With no moving mechanical parts, the pump electrically generates osmotic pressure in an electrolyte, according to a Stanford website.

"With no moving parts to wear out, this noiseless pump -- the first of its kind -- is small, cost-effective and highly reliable for long-term use," the company said.

The cooling system can handle 1,000 watts per square centimeter, the company claims. Passive cooling systems can cool only 250 watts per square centimeter, according to the company.

The technology was originally developed at Stanford under Darpa's Heretic program, an effort to develop solid-state, heat-dissipation devices for microelectronics and photonics.

Apple Computer, Advanced Micro Devices and Intel also cooperated, the company said. "The Intel test produced the highest performance Intel had ever seen from any cooling technology," Cooligy said.

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The company said it is developing the technology for the "next generation of workstations, servers and high-end PCs." But at Stanford, the technology was demonstrated on a notebook computer.

Earlier this year, Apple CEO Steve Jobs said his company would like to develop a PowerBook portable based on the new 64-bit PowerPC G5 chip, but to do so probably would require some kind of liquid-cooling technology.

PC manufacturers already sell water-cooled laptops.

Last year, Hitachi released a line of Flora notebooks that dispense with noisy cooling fans in favor of a silent water-cooling system. Meanwhile, IBM is moving toward similar technology with a system of heat pipes called a "thermal hinge" used in some ThinkPad notebooks.

On the desktop, liquid cooling is far from new, and has been used in mainframes and supercomputers for decades. Off-the-shelf cooling systems for overclocked PCs can be bought from dozens of hobbyist suppliers.

Apple, Intel, DARPA and Cooligy did not respond to requests for comment.
